

**ATTACHMENT 1**  
**RDJ-3-33600**  
**STATEMENT OF WORK**

**“Outdoor Testing and Monitoring of Thin Film Modules in Hot and Humid Climates”**

**November 25, 2002**

**1.0 BACKGROUND**

The purpose of the Thin-Film Photovoltaic Partnership Program (TFPPP) is to accelerate the progress of thin film solar cells and module development as well as to address mid- and long-term research and development issues. The long-term objective of the TFPPP is to demonstrate commercial, low-cost, reproducible, high yield and *robust modules having a stable, 15% efficiency*.

This Statement of Work (SOW) focuses on improving the stability of thin film modules by testing and monitoring the modules outdoors, in high-humidity and high-temperature conditions. Modules that will be tested are expected to be leading-edge prototypes being developed for commercial use. Module manufacturers will choose those designs (e.g., with or without frames, experimental edge seals, etc.) that are most likely to lead to greater insights into packaging issues. Participation of the awardee(s) in the Thin Film Module Reliability National Team is required.

The purpose of this SOW is to establish a program to (1) test and monitor outdoors (at high temperature and humidity) sets of CdTe and CIS modules, (2) maintain these tests for the time needed to observe problems (up to 3 years), and (3) develop a testing and monitoring capability that can respond to further requests for similar tests.

**2.0 OBJECTIVES**

The primary objectives of this research are:

1. To test sets of CIS and/or CdTe modules outdoors in high humidity/temperature to determine failure mechanisms;
2. Set up an organizational capability to continue to respond to requests for similar tests.

### 3.0 SCOPE OF WORK AND TASKS

The scope of work under this subcontract entails the investigation of thin film module reliability outdoors under hot/humid conditions. Offeror must bid on performing this work for **all three (3) sets of modules**. The module types are expected to be as follows:

1. CdTe on glass/glass (1 kind)
2. CIS on glass/glass (1 kind)
3. CIS on a flexible substrate/flexible encapsulant (mounted on fiberglass).

**Table 1. Type of Modules Expected**

Technology	Sizes	Output (W)*	Voltage ( $V_{oc}$ ; $V_{mp}$ )*	Company
Glass/CdTe/glass	2 ft by 4 ft	50-70	90 V; 60 V	First Solar
Glass/CIS/Glass	1 ft by 4 ft	36-45	25 V; 17 V	Shell
CIS flexible, fiberglass backing	25 in by 55 in	44-48 W	100 V; 40 V	Global Solar

\* approximate ranges

For each set of module types (i.e., CIS on glass, CdTe on glass, etc.), Offeror should be prepared to receive (at no cost to the Offeror) the following modules:

1. About 30 modules to be placed outdoors at maximum power using a resistive load *monitored as an even number of strings with modules wired in series to plus and minus the manufacturer's recommended maximum system voltage* (see Table 2).
  - For example, if the maximum system voltage is 600 V and it takes 24 modules to reach that, then 2 strings of 24 modules each will be set up (one to +600 V, the other to -600 V); if the maximum is 50 V and it takes 2 to reach that, then 14 strings of 2 modules each will be set up.
2. (*Optional*) Two modules to be tested in the same location for leakage current. The modules shall be set up at high voltage at opposite polarities for individual monitoring and data acquisition. Leakage current to ground shall be measured and recorded no less frequently than once per minute and averaged every 15 minutes. {Since this test can potentially introduce artifacts and degradation, final procedures will be developed with guidance from NREL.}

In addition to three (3) sets of the above-stated modules, Offeror shall be prepared to receive (at no cost): Two crystalline silicon modules to be placed outdoors side-by-side with the thin film modules.

*As stated above, the leakage current testing is NOT required. Every proposal **must** address the first activity – setting up CIS, and CdTe module strings; but it is at the discretion of the Offeror whether to propose the leakage current testing. NREL makes no commitment to fund this optional activity with any Offeror, even if the rest of the proposed work is funded.*

Thus the Offeror will receive and test *about* 110 CIS and CdTe modules in strings (see Tables); eight (8) optional modules for leakage current (2 of each CIS and CdTe kind); and two crystalline silicon modules.

**Table 2. Likely Approximate Recommended System Voltage for CIS and CdTe**

Technology	Recommended Maximum System Voltage*	Number of Modules to Meet Rating*	Total Number of Modules Expected*	Company
Glass/CdTe/glass	600 V	10	30	First Solar
Glass/CIS/Glass	600 V	24	50	Shell
CIS flexible, fiberglass backing	48 V	2	30	Global Solar

\* estimated - will be finalized during negotiations

Each test site shall be monitored in such a way as to (1) record real-time irradiance, weather, and string output data and (2) detect module changes as soon as possible so that they can be reported to the supplier and NREL.

NREL and the supplier will baseline modules before they arrive at the deployment site. Offeror shall also perform a simple visual baseline of the modules as follows:

**Baselining prior to deployment shall include:**

- Examination following the visual inspection standard from ASTM E1799, “Standard Practice for Visual Inspection of PV Modules.”

Other minimum requirements include:

**In general, periodic and continuous outdoor module data acquisition and monitoring shall include:**

- Visual (repeat monthly ASTM E1799, e.g., pictures of corrosion, hot spot, delamination, bubbles, discoloration, de-bonding, visible moisture. Optional monitoring can include infrared imaging, etc.);
- Continuously measure and record the voltage across the load resistance for each string (other equivalent and additional measurements may be proposed), but not for the optional high-voltage modules;
- Other, optional module/string performance measurements can be proposed.

**Weather conditions that shall be monitored and recorded in a useful manner at the site, to include:**

- Ambient temperature (15 minute, or shorter, average),
- Relative humidity (15 minute, or shorter, average),
- Wind speed (15 minute, or shorter, average, plus maximum speed in interval),
- Plane of array total irradiance (15 minute, or shorter, average),
- Diffuse horizontal total irradiance (15 minute, or shorter, average),
- Plane of array total UV irradiance (15 minute, or shorter, average),
- Module temperature (back-of-module temperature on the 2 grounded modules in each set (one per string; 15 minute, or shorter, average),
- Drastic weather events such as storms, lightning, high wind.

At a minimum, data shall be in an acceptable electronic format (on a quarterly basis), which will be approved by NREL in advance.

Modules shall be mounted as open frame rack arrays at latitude tilt.

Offeror may suggest any *other innovative and valuable additions to this list to distinguish their proposal*.

Once deployed, any significant module visual or performance changes shall be communicated to the manufacturer and NREL immediately. Upon request, the Offeror shall carefully ship selected modules (in pre-defined and NREL-approved packaging) back to NREL and be prepared to accept replacements. NREL will re-baseline the modules. In addition, NREL will work with the module supplier to define an approach to diagnose the degradation mechanism.

Offeror shall be prepared to maximize productivity by (1) working on an as-needed basis with NREL experts and (2) working with the Thin Film Module Reliability Team. Where possible (and when data can be presented without specified confidentiality concerns), Offeror shall be expected to share data and insights with the National Team.

In accordance with the above scope of work, background, and objectives, the Subcontractor shall perform the following specific tasks *for each set of module types. {Describe module type and specifics of approach for each type of module. Creative solutions are welcome that expand upon the intentions of the SOW.}*

## Tasks

### Phase One

1.0 Consult with Module Suppliers and NREL to create a Test Plan for Each Set of Modules. The Test Plan is a specific plan of deployment, monitoring, data acquisition and failure detection for each module set and shall include but not be limited to array design and safety, monitoring of modules and weather, approach to detecting module changes, and communications feedback loop with NREL and supplier, with a proposed reporting format for electronic distribution of test data. A draft Test Plan shall be submitted to NREL for approval and any comments. The final Test Plan shall incorporate NREL feedback

1.1 Baseline Modules as described above

1.2 Set Up Monitoring Capabilities (as per accepted Test Plan)

1.2.1 Procure correct monitoring and data acquisition equipment

1.2.2 Build array structures and safety systems

1.2.3 Install and debug monitoring and data acquisition equipment

1.3 Install Modules and Connect Electronics

1.3.1 Install modules

1.3.2 Test safety systems

1.3.3 Connect monitoring and data acquisition equipment to modules

1.3.4 Begin module and weather data acquisition

1.3.5 Provide initial outdoor test data in approved electronic format for NREL and supplier examination.

1.4 Data Acquisition of Module and Weather Data

1.4.1 Record module and weather data as described above

1.4.2 Observe the condition of each module monthly (using ASTM standard)

1.4.3 Inspect system-related components and insure dependability of wiring and equipment

1.4.4 Host a NREL inspection visit (with supplier participation optional) and respond to any suggested improvements.

1.5 Remove Modules with Observed Problems

1.5.1 Remove and document modules as per ASTM standard

1.5.2 Package and Safely Ship Modules to NREL

1.5.3 Adopt any reasonable, adjusted follow-up test and monitoring procedures suggested by NREL or by manufacturer, if any

## Phase Two

### 2.1 Monitor Modules and Weather

- 2.1.1 Record module and weather data as described above
- 2.1.2 Observe the condition of each module monthly (using ASTM standard)
- 2.1.3 Inspect system-related components and ensure dependability of wiring and equipment

### 2.2 Remove Modules with Observed Problems

- 2.2.1 Remove and document modules as per ASTM standard
- 2.2.2 Package and safely ship modules to NREL
- 2.2.3 Adopt any reasonable, adjusted follow-up test and monitoring procedures suggested by NREL or by manufacturer, if any

## Phase Three

### 3.1 Monitor Modules and Weather

- 3.1.1 Record module and weather data as described above
- 3.1.2 Observe the condition of each module monthly (using ASTM standard)
- 3.1.3 Inspect system-related components and insure dependability of wiring and equipment

### 3.2 Remove Modules with Observed Problems

- 3.2.1 Remove and document modules as per ASTM standard
- 3.2.2 Package and Safely Ship Modules to NREL
- 3.2.3 Adopt any reasonable, adjusted follow-up test and monitoring procedures suggested by NREL or by manufacturer, if any

## **4.0 MILESTONES**

Subcontractor shall perform each of the above tasks with the goal of meeting the following milestones (provide milestone schedule assuming modules are received in a timely manner):

### Phase One

- 1.1 Work with module suppliers and NREL to develop the Test Plan (per Task 1.0 above.)
- 1.2 Procure equipment and set up monitoring and data acquisition capabilities for each module set and test
- 1.3 Install set(s) of modules outdoors
- 1.4 Provide initial outdoor test data for NREL and supplier examination.
- 1.5 Soon after initial data, host a NREL and supplier (optional) inspection visit and respond to any suggested improvements
- 1.6 Supply quarterly electronic data from data acquisition

### Phase Two

- 2.1 Supply quarterly electronic data from data acquisition

### Phase Three

- 3.1 Supply quarterly electronic data from data acquisition
- 3.2 Prepare final technical report per Section 6.0 below.

## 5.0 DELIVERABLES

The following deliverables shall be completed and delivered to NREL by the dates indicated:

No.	Deliverable Description	Due Date
<b>Phase I</b>		
D.1.1	Draft Test Plan	6 weeks after receipt of information from module suppliers
D.1.2	Final Test Plan	2 weeks after receipt of NREL comments
D.1.3	Initial Outdoor Test Data	1 week prior to inspection visit
D.1.4	1 <sup>st</sup> Quarterly Report	15 days after quarter*
D.1.5	2 <sup>nd</sup> Quarterly Report	15 days after quarter
D.1.6	3 <sup>d</sup> Quarterly Report	15 days after quarter
D.1.7	4 <sup>th</sup> Quarterly Report	15 days after quarter
D.1.8	PV Program Contract Summary Report	By December 15
<b>Phase II</b>		
D.2.1	1 <sup>st</sup> Quarterly Report	15 days after quarter
D.2.2	2 <sup>nd</sup> Quarterly Report	15 days after quarter
D.2.3	3 <sup>d</sup> Quarterly Report	15 days after quarter
D.2.4	4 <sup>th</sup> Quarterly Report	15 days after quarter
D.2.5	PV Program Contract Summary Report	By December 15
<b>Phase III</b>		
D.3.1	1 <sup>st</sup> Quarterly Report	15 days after quarter
D.3.2	2 <sup>nd</sup> Quarterly Report	15 days after quarter
D.3.3	3 <sup>d</sup> Quarterly Report	15 days after quarter
D.3.4	Draft Final Technical Report	60 days prior to end of period of performance
D.3.5	Final Technical Report	By end of period of performance
D.3.6	PV Program Contract Summary Report	By December 15

- The first quarter is defined as the first three (3) month period from the effective (or award date) of the subcontract.

## 6.0 REPORTING, PRESENTATION/TRAVEL REQUIREMENTS, AND DELIVERABLE/REPORT DISTRIBUTION

**Presentations and Review Meetings** - Subcontractor shall attend and participate in the following meetings and presentations:

- NCPV Program Review Meetings to be held every 18 months at a place and time specified by NREL. Subcontractor shall present a discussion of work performed under the subcontract to date.



- Thin Film Module Reliability Team Meetings to be held twice per year at a place and time specified by NREL.

**Test Plan** – This report is described in Task 1.0 above and is due in draft and final forms as per the table in Section 5.0 – Deliverables.

**Quarterly Status Reports** - Quarterly Status Reports to communicate to NREL an assessment of subcontract status, to explain variances and problems, to report accomplishments of tasks, milestones, and program deliverables, and to discuss any other areas of concern or achievements, *especially data interpretation*. This report shall be two (2) to six (6) pages (except see below), written in a letter format with emphasis placed on the status rather than a description of the progress. This report is due on or before fifteen (15) days after completion of each subcontract quarter, per the deliverable schedule above. A required appendix (by reference only) of quarterly electronic data must be supplied as well, in electronic form.

Proprietary information may be included in the Quarterly Reports (see above section, Handling of Information), but should be prominently marked. If, after an agreement with the module supplier, such information in the report is considered public, NREL may distribute the reports publicly. Otherwise, they will not be distributed publicly.

Quarterly reports shall be accompanied by an appendix of electronic data, as required in the milestones.

**PV Program Contract Summary Report** – A two-page PV Program Contract Summary Report (per DOE requirements) shall be submitted by December 15 of each calendar year during the period of performance.

**Final Technical Report** – A formal, structured technical report, both in draft and final versions, shall describe all significant work performed during the entire subcontract's period of performance. This report is in lieu of the last Quarterly Report.

The draft version of this report is due at NREL for review on or before thirty (30) days prior to the completion date for this subcontract. The Subcontractor shall make any corrections or revisions per NREL direction. The Subcontractor shall submit the Final Technical Report no later than fifteen (15) days after receipt of NREL's feedback and recommendations. NREL will distribute the Final Technical Report, therefore no proprietary information should be included by the Subcontractor.

**Report Formatting** - Guidance for report formatting can be found in NREL's Style Guide at:

<http://www.nrel.gov/docs/gen/fy01/24935.pdf>

Guidelines for the submittal of the electronic master of the Final Technical Report are as follows:

NREL prefers reports with embedded graphics that can be immediately converted to a PDF format. As a minimum, submit a word processing file prepared with one of the following software packages (in order of preference):

- MS Word (Mac, DOS, or Windows)
- Word Perfect
- Text Files (ANSI, ASCII, .TXT, etc.)

If graphics cannot be embedded in the report file, NREL prefers one of the following graphics formats: .EPS, .TIF, .GIF, .JPG, .WPG, .CGM, .WMF, PCT. Documents prepared in portable document file (.PDF) format should be kept to a manageable size not exceeding 1 MB. Often, this will require breaking documents into smaller sections.

**Submittal of Reports and Deliverables** – Subcontractor shall *clearly label all deliverables with the subcontract number, the deliverable number, the deliverable description, the date, and the Subcontractor's name*. Subcontractor shall submit the following reports to NREL as follows:

Quarterly Status, Test Plan, and PV Program Contract Summary Reports Subcontractor shall submit hard copies of these reports as follows:

- The original and *four (4) copies* to the NREL Technical Monitor, address below.
- One (1) printed copy to the NREL Subcontract Associate, address below.
- Quarterly data from outdoor tests in suitable electronic form to the Technical Monitor

*(Overlooking this requirement may cause substantial delay in receiving payment.)*

Draft and Final Technical Reports - The Draft Final Technical Report shall be submitted via e-mail to the NREL Technical Monitor. The Final Technical Report shall be submitted in hard copy and in electronic format so that it can be posted on NREL's Internet site and distributed in electronic form. Subcontractor shall submit the Final Technical Report as follows:

- One (1) master electronic version to the NREL Technical Monitor.
- One (1) printed master copy, including graphics, and *four (4) copies* to the Technical Monitor.
- One (1) printed copy to the NREL Subcontract Associate.

*(Overlooking this requirement may cause substantial delay in receiving payment.)*

**Addresses –**

**Deliverable electronic data and reports (per above) shall be submitted to the NREL Technical Monitor at:**

Ken Zweibel, MS 3212  
Ken\_Zweibel@nrel.gov  
National Center for Photovoltaics  
National Renewable Energy Laboratory  
1617 Cole Boulevard  
Golden, CO 80401

**Hard copies of all reports (and copies of transmittal letters for samples and other deliverables), shall be submitted to the NREL Subcontract Associate at:**

Carolyn Lopez, MS 2713  
Contracts and Business Services Office  
National Renewable Energy Laboratory  
1617 Cole Boulevard  
Golden, CO 80401